



# Climate Change

## Earth's Atmosphere

Our Earth is surrounded by layers of gases called the atmosphere. Without these gases in the atmosphere, the Earth would be so cold that almost nothing could live. It would be a frozen planet. Our atmosphere keeps us alive and warm.

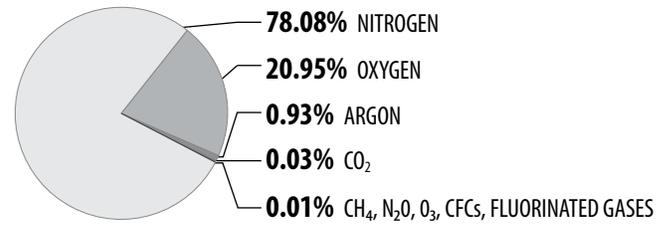
The atmosphere is made up of many different gases. Most of the atmosphere (99 percent) is comprised of oxygen and nitrogen gases. Less than half of one percent is a mixture of heat-trapping gases. These heat-trapping gases are mostly water vapor mixed with carbon dioxide, methane, nitrous oxide, and F-gases. These are called **greenhouse gases (GHG)**.

- **Water vapor** ( $H_2O$ ) is produced naturally through evaporation. It is the most abundant and important GHG. Human activities have little influence on the concentration of water vapor in the atmosphere. However, a warmer climate increases evaporation and allows the atmosphere to hold higher concentrations of water vapor.
- **Carbon dioxide** ( $CO_2$ ) is produced naturally through plant, animal, and human respiration and volcanic eruptions. Carbon dioxide is mostly produced through human activities such as **combustion** of fossil fuels and biomass, industrial processes, and deforestation.
- **Methane** ( $CH_4$ ) is produced naturally when organic matter decays during wildfires, and from animals. Human activities are responsible for methane emissions from the production and transport of fossil fuels, managing livestock waste, and landfill decay.
- Nitrous oxide ( $N_2O$ ) comes from the bacterial breakdown of nitrogen in soil and the oceans. Human activities contribute to nitrous oxide emissions through agricultural and industrial activities, the combustion of fossil fuels, and sewage treatment.
- Tropospheric, or ground-level, **ozone** ( $O_3$ ) is produced in the atmosphere when chemicals from human activities interact with sunlight. These emissions are from automobiles, power plants, and other industrial sources.

## GREENHOUSE



## Major Gases in the Atmosphere (Dry)



Note: These percentages represent atmospheric composition for a completely dry atmosphere. Water vapor is nearly always present, but concentration varies based on location. Atmospheric composition changes with the addition of water vapor.

Data: NASA

▪ **F-gases** are synthetically sourced substances, also known as fluorinated gases. This group of chemicals is made of bonded halogen and carbon atoms and depending on the combination, can have a variety of uses, including insecticides, coolants, solvents, propellants, and electricity production. The presence of F-gases in the atmosphere is due to human activities. Certain types of F-gases (CFCs and HCFCs) have been or will be phased out internationally, due to their long atmospheric lifetimes and their role in ozone depletion in the stratosphere.

## Sunlight and the Atmosphere

Rays of sunlight (radiant energy) shine down on the Earth every day. Some of these rays bounce off of molecules in the atmosphere and are reflected back into space. Some rays are absorbed by molecules in the atmosphere and are turned into thermal energy.

About half of the radiant energy passes through the atmosphere and reaches the Earth. When the sunlight hits the Earth, most of it is converted into heat. The Earth absorbs some of this heat; the rest flows back out toward the atmosphere. This outward flow of heat keeps the Earth from getting too warm.

When this out-flowing heat reaches the atmosphere, most of it is absorbed. It can't pass through the atmosphere as readily as sunlight. Most of the heat becomes trapped and flows back toward the Earth again. Most people think it is sunlight that heats the Earth, but actually it is this contained heat that provides most of the warmth.

## The Greenhouse Effect

We call the trapping of **thermal energy** by the atmosphere the **greenhouse effect**. A greenhouse is a building made of clear glass or plastic in which we can grow plants in cold weather. The glass allows the sunlight to pass through, and it turns into heat when it hits objects inside. The heat becomes trapped. The **radiant energy** can pass through the glass; the thermal energy cannot.

What is in the atmosphere that allows radiant energy to pass through but traps thermal energy? It is the presence of greenhouse gases—mostly carbon dioxide and methane. These gases are very good at absorbing heat in the atmosphere, where it can flow back toward Earth.

According to studies conducted by NASA, the National Aeronautics and Space Administration, and many other researchers around the world, the concentration of carbon dioxide has increased by nearly 50 percent since the Industrial Revolution in the late 18<sup>th</sup> century. Climate change experts have concluded that this increase is due primarily to the expanding use of fossil fuels.

In addition to the increase in the level of carbon dioxide, there has also been a substantial rise in the amount of methane in the atmosphere. While there is much less methane in the atmosphere than carbon dioxide, it is 21 times more effective than carbon dioxide at trapping heat. However, it does not remain intact as long in the atmosphere, only about 12 years.

Fluorinated gases are the best GHGs at trapping heat. While their concentrations are very low, they are 140 to 23,900 times more effective at absorbing heat than carbon dioxide. Fluorinated gases have extremely long atmospheric lifetimes, up to 50,000 years. In addition, scientists expect concentrations of fluorinated gases to increase faster than some other GHGs.

## Global Climate Change

Increased levels of greenhouse gases are trapping more heat in the atmosphere. This phenomenon is called global **climate change** or **global warming**. According to NASA, the average temperature of the Earth has risen by a little over 1°C (1.8°F) since 1880, with the majority of warming occurring after 1975. This increase in average temperature has been the major cause of a 21-24 centimeter rise in sea level over that time period, as well as an increase in extreme precipitation events. Sea levels are rising because sea water expands as it warms and land-based ice is melting in the Arctic, Antarctic, and in glaciers. Regions such as the Gulf Coast of the United States and several Pacific islands have already experienced losses to their coastlines. Recent research has also linked the increased severity of hurricanes and typhoons to global warming.

Climate scientists use sophisticated computer models to make predictions about the future effects of climate change. Because of the increased level of carbon dioxide and other GHGs already in the atmosphere, the Intergovernmental Panel on Climate Change (IPCC) forecasts at least another 1.8 - 6 degrees Fahrenheit temperature increase over the next century. The climate models predict more floods in some places and droughts in others, along with more extreme weather, such as powerful storms and hurricanes. They predict an additional rise in sea level of up to two feet in some areas, which would lead to the loss of low-lying coastal areas.

These predictions have led many scientists to call for all countries to act now to lower the amount of carbon dioxide they emit into the atmosphere. Countries around the world are working to determine ways to lower the levels of carbon dioxide in the atmosphere, while minimizing negative impacts on the global economy.

## International Awareness

Climate change is impacting every person around the globe, so climate change is an international issue. There has been a history of the international community coming together to try and make plans to combat rising levels of greenhouse gases. In 1997, the Kyoto Protocol was the first step in coming to an international agreement on greenhouse gas levels. The United States did not ratify the Kyoto Protocol because it did not include targets or timetables outlined for developing nations as well as industrialized nations.

This agreement expired in 2012 and, in an attempt to continue international efforts, world leaders continue to meet periodically. One of the main roadblocks is regulating GHG emissions from developing

## The Greenhouse Effect

Radiant energy (light rays) shines on the Earth. Some radiant energy reaches the atmosphere and is reflected back into space. Some radiant energy is absorbed by the atmosphere and is transformed into thermal energy (dark arrows).

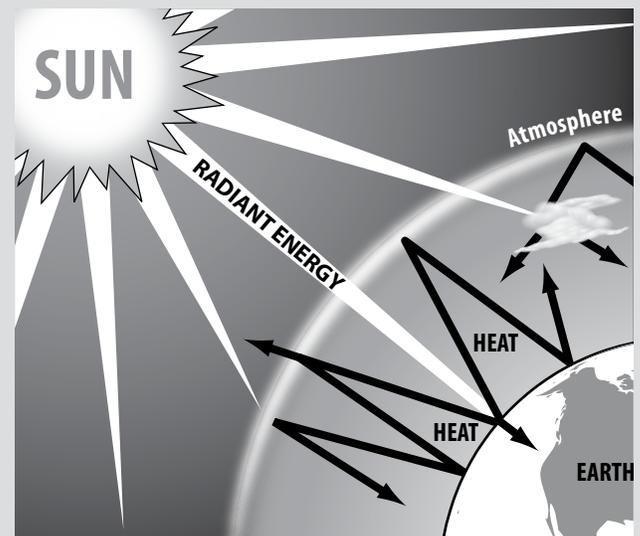
Half of the radiant energy that is directed at Earth passes through the atmosphere and reaches the Earth, where it is transformed into thermal energy.

The Earth absorbs some of this thermal energy.

Most of the thermal energy flows back into the air. The atmosphere traps the thermal energy.

Very little of the thermal energy escapes back into space.

The trapped thermal energy flows back toward the Earth.



countries. These nations argue that since current climate change was primarily caused by emissions from the developed, industrialized countries, those countries should bear the responsibility of lowering emissions. They see limits on GHGs as a limit to their development and their efforts to bring millions of their citizens out of poverty. While the developed nations accept that they need to curb their emissions, they feel that developing nations will have an unfair economic advantage if they are not regulated. An international conference in Copenhagen, Denmark in 2009 ended without a strong agreement on how to regulate emissions globally. In 2015 the UN and EU hosted climate talks in Paris. The Paris Agreement set out a global plan of action to limit warming to below 2°C. The agreement has been ratified by 179 of the 197 Parties to the Convention and is a legally binding treaty. The U.S rejoined this agreement in early 2021.